# WHEAT RESPONSE TO SOIL WATER RETENTION AND DYNAMICS UNDER CONSERVATION TILLAGE IN DRYLAND POTHWAR, PAKISTAN

**Rana Muhammad Ammar Asghar[1], Muhammad Ayaz[2*], Shahzada Sohail Ijaz[1], Muhammad Ali[3], Muhammad Sharif[3], Mohsin Nadeem[1], Salman Ali[2] and Bibi Ayesha[4]**

[1]Department of Soil Science & SWC, PMAS-Arid Agriculture University Rawalpindi, Murree Road, Rawalpindi Pakistan.

[2*]State key laboratories, college of Resources and Environment, Northwest A&F university, yangling 712100, P.R China

[3]Department of Agriculture, The University of Agriculture Peshawar, KP, Pakistan

[4]Department of Environmental Sciences Northern University of Science and Technology.

*Corresponding author's Email: muhammadayaz111@yahoo.com

***ABSTRACT:*** *A field study was conducted during 2014 in fourth year of a medium-term conservation tillage experiment at Pothwar dryland Rawalpindi, Pakistan. The soil was sandy clay loam of Kahuta soil series belonging to Udic Haplustalfs. The objectives were to investigate the wheat performance in response to changes in soil water retention and related physical properties under different variants of conservation tillage. The treatments were arranged in a split-plot design having Minimum tillage (MT), Chisel plough (CP), Zero tillage (ZT), and Conventional tillage (CT, control) in main plots and residue retained and removed in subplots. Field capacity and permanent wilting point were highest under chisel plow (35.6% and 8.3%, respectively) while lowest under zero tillage (23.9% and 6.0%, respectively). The highest infiltration rate was also under chisel plow (196.5 mmh$^{-1}$) and least under zero tillage (29.5 mmh$^{-1}$). Consequently, volumetric water content was significantly higher in chisel plow as compared with all other treatments at both 0-15 cm and 15-30 cm depths throughout the crop period. The bulk density was the maximum in zero tillage (1.56 and 1.60 Mg m$^{-3}$) while minimum in conventional tillage (1.24 and 1.27 Mg m$^{-3}$) at 0-15 and 15-30 cm depths, respectively. The residue incorporation averagely enhanced infiltration rate by 35.4% and grain yield by 29.26% than residue removal. The grain yield was statistically similar under all tillage systems. Conservation tillage showed better moisture capture, retention and availability to wheat crop while providing equivalent yield to current tillage practices in dryland Pothwar.*

**Key words:** Chisel plow, Zero tillage, Residue management, Infiltration, Moisture Content, Wheat

## INTRODUCTION

Tillage influences soil natural phenomenon and ecological processes leading to remarkable changes in soil properties. Conservation tillage is defined as any tillage or planting system in which at least 30% of the soil surface is covered by plant residue reducing water and wind erosion [7,9,28] The term includes minimum tillage, direct drilling, zero tillage and no-till etc. under its umbrella. It breaks the plough pans [17], results in conservation of natural or other resources [10], conserves water, protects the topsoil, reduces soil compaction, provides protection from the impact of rain drop, so that it improves the soil condition compared with conventional intensive tillage systems [26;19]. Conventional tillage that involves several plowings and disking to prepare soil for plantation, and sometimes harrowing and dragging during or after plowing to control weeds [19]. It leaves less than 15% crop residue over the soil surface.

In dryland Pothwar region of Pakistan, climate is semi-arid to sub-humid, sub-tropical continental where water is the most limiting factor for crop production. The occurrence of rainfall is unpredictable with high spatial and temporal variation and 70% rainfall is received during summer monsoon and temperatures may rise as high as 50 °C [6]. Further, the duration of fallow period is six months that involves intensive conventional tillage practices [1,18,21,23]. The routine tillage practice in the area is heavy plowing with moldboard plow followed by repeated cultivation with tine cultivator for weed control and planking for seed bed preparation, which causes soil physical disintegration, oxidation and microbial decomposition of soil organic matter and structural aggregates [16], the repeated plowing at the same depth also creates hard pan that causes a blockage in the infiltration of water and entry of plant roots.

Many studies in the irrigated rice-wheat cropping systems of Pakistan have revealed that conservation tillage practices can increase soil water and nutrient contents, improve soil structure and increase crop yields [11;15;30]. However, fewer studies have reported the effects of conservation tillage in dryland areas of Pakistan.

Therefore, the present study was carried out to investigate the effects of different tillage techniques on temporal soil water changes, bulk density, infiltration rate, field capacity and permanent wilting point and to observe the effects of these changes on wheat production.

## MATERIALS AND METHODS

**Experimental Site and Treatments:** The study was conducted in an ongoing field experiment initiated in 2011 at PMAS-Arid Agriculture University Research Farm, Chakwal Road (33°11'N, 73°01'E). The research farm is situated in semiarid, subtropical continental zone at an altitude of 517.6 m. Experimental soil was sandy clay loam with sand 56%, silt 22.8% and clay 21.2% classified as Kahuta soil series belonging to Udic Haplustalfs. The research was conducted during wheat growing season of year 2013-14. The treatments were arranged in split-plot design replicated four times. The total experimental area was 100 m × 60 m (6000 m$^2$) which was divided into sixteen main plots of 27 m × 11 m (297m$^2$) and each main plot was divided into equal halves as subplots. Main plot treatments during summer fallow period were: Conventional tillage (CT, moldboard ploughing at monsoon start and cultivation after each rainfall), Minimum tillage (MT, moldboard ploughing at starts of monsoon, one cultivation at wheat sowing and weed control by cultivator when necessary), Reduced tillage (RT, chisel plowing at the start of monsoon, weed control by chemical and wheat sown with zero tillage drill, and Zero tillage (ZT, no tillage during fallow period, summer weeds controlled through chemical herbicide and crop sown with zero tillage drill). And sub-plot treatments were, residues retained (+R) and residues removed (–R).

In CT plots, the soil was ploughed with moldboard plow at the start of monsoon followed by 8-10 time shallow cultivation with tine cultivator applied after each major rainfall for weed control and moisture conservation. Wheat sowing in these plots was done with seed-cum-fertilizer drill. In MT, the field was also ploughed with intensive moldboard on the onset of monsoon and four time cultivation with tine cultivator, while sowing was done with conventional seed-cum-fertilizer drill. In RT, one time chisel plough was applied at the start of monsoon and then during fallow period weeds were controlled with roundup herbicide (Glyphosate @ 1 L acre$^{-1}$) and wheat was sown through direct drilling with zero tillage drill. In ZT, field remained undisturbed for entire fallow period and weeds were controlled with roundup herbicide when needed. Winter wheat was directly sown with zero tillage drill. In sub-plot treatments +R involved harvest just spikes from the previous crop and retention of all the stubbles in field. In case of -R the crop was harvested with reaper and there was no crop residues left in field except stubbles. The recommended doses of fertilizer NPK i.e. 100-60-30 in the form of urea, diamonium phosphate (DAP) and sulfate of potash (SOP) were used. Wheat was planted on 20 October 2013 at seed rate of 100 kg ha$^{-1}$ and was harvested manually on 5 May 2014.

**Related Soil Physical Properties:** Gravimetric water content ($\theta_m$) was determined at different stages of crop growth 0, 102, 158, 165, 172, 182, 187 and 197 days after sowing (DAS) with respect to each treatment and then converted in to volumetric moisture content (m$^3$ m$^{-3}$) by multiplying with bulk density [27]. The field capacity and permanent wilting point were measured with pressure membrane apparatus at 33 and 1500 kPa, respectively [22]. Infiltration was measured using double ring infiltrometer [4]. Soil bulk density was determined from core samples collected with core sampler of 5 cm diameter and 5 cm length. The soil from cores was weighed after oven drying at 105˚C for 24 hours [9].

**Crop data:** The leaf area index (LAI) was measured at different stages of crop growth *i.e.* 0, 102, 158, 165, 172, 182, 187 and 197 DAS. The LAI was measured by formula given by Dwyer and Stewart (1986):

$$\text{Leaf area index (LAI)} = L \times W \times A$$

Where L is leaf length, W is the greatest leaf width and A is factor having value of 0.80 for wheat crop. Plant heights of five plants selected randomly were measured at physiological maturity using meter rod. At harvest grains were separated from spikes and average grain yield was presented in kg ha$^{-1}$.

**Metrological data:** Daily metrological data on daily air temperature, humidity, rainfall, solar radiation, pan evaporation and wind speed of Chakwal district (Figure 1) was acquired from Pakistan Meteorological Department Headquarter Office, Islamabad.

**Statistical analysis:** The data collected for various characteristics were subjected to analysis of variance (ANOVA) using split-plot design with tillage systems as main-plot and residue management as sub-plots. The means were compared at 5% level of significance by Least Significance Difference (LSD) test [25].

## RESULTS AND DISCUSSION

**Bulk Density:** Statistically highest bulk density of soil was observed in plots under zero tillage that was followed by chisel plow and then conventional and minimum tillage practices (Figure 2). All the tillage treatments showed significant lower bulk density when residue was applied as compared with no residue.

High bulk density in zero tillage plots may be due to the fewer disturbances which increased soil compaction. However, the zero tillage and chisel plow plots are expected to have lower bulk densities over time with the buildup of organic matter [13]. The least bulk density in conventional tillage treatment is due to repeated cultivation for weed control that produced more fine and pulverized soil [11].

**Infiltration:** The highest infiltration rate of soil was observed in plots tilled with chisel plow followed by conventional tillage and minimum tillage plots (Figure 3). But zero tillage showed significantly lower infiltration than other treatments. All the tillage treatments had significantly higher infiltration rate when residue was applied as compared with no residue. Thus the interaction of chisel plow with residue application significantly had higher infiltration rate as compared to other treatment combinations.

The chisel opened the soil more than other tillage treatments and allowed the entry of more water resulting in higher infiltration rate. Also the chisel plow breaks lesser aggregates and decomposes less organic matter [11] which might also have increased the macroporosity of the soil over time thus the ease of water inflow. On the contrary moldboard plow causes breakdown of aggregates [24], loss of organic matter [12] and establishment of hardpan [29] below the plowing depth. These factors could have contributed to reduced infiltration rate in moldboard plow. The low water infiltration under zero tillage might be due higher bulk density as shown in Figure 2.

**Field Capacity and Permanent Wilting Point:** Statistically highest field capacity as well as permanent wilting point of soil was observed in plots tilled with chisel plow (Figure 4 a & b), followed by conventional tillage and minimum tillage, but zero tillage showed significantly low field capacity and permanent wilting point than other treatments. No significant difference in field capacity was observed when residue application was compared with no residue, except in zero tillage. However, residue retaining plots had higher permanent wilting point under chisel plow and zero tillage.

.

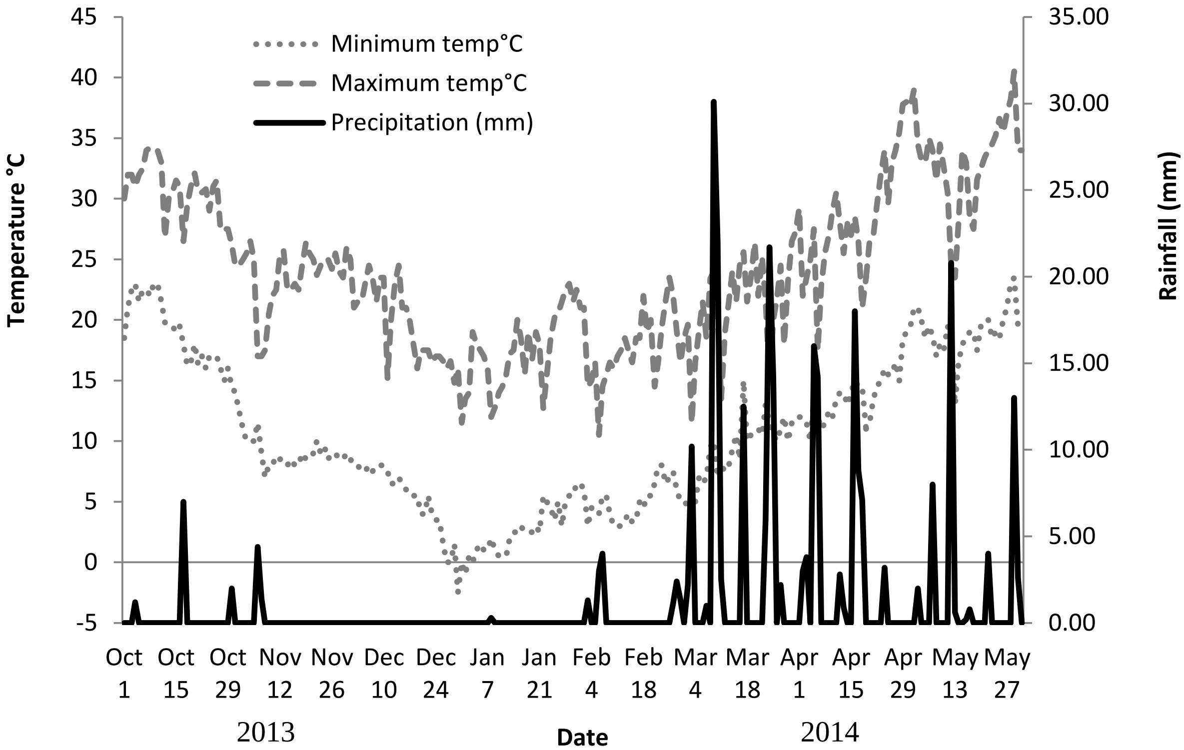


**Figure 1. Rainfall, maximum and minimum temperature during experimental period.**

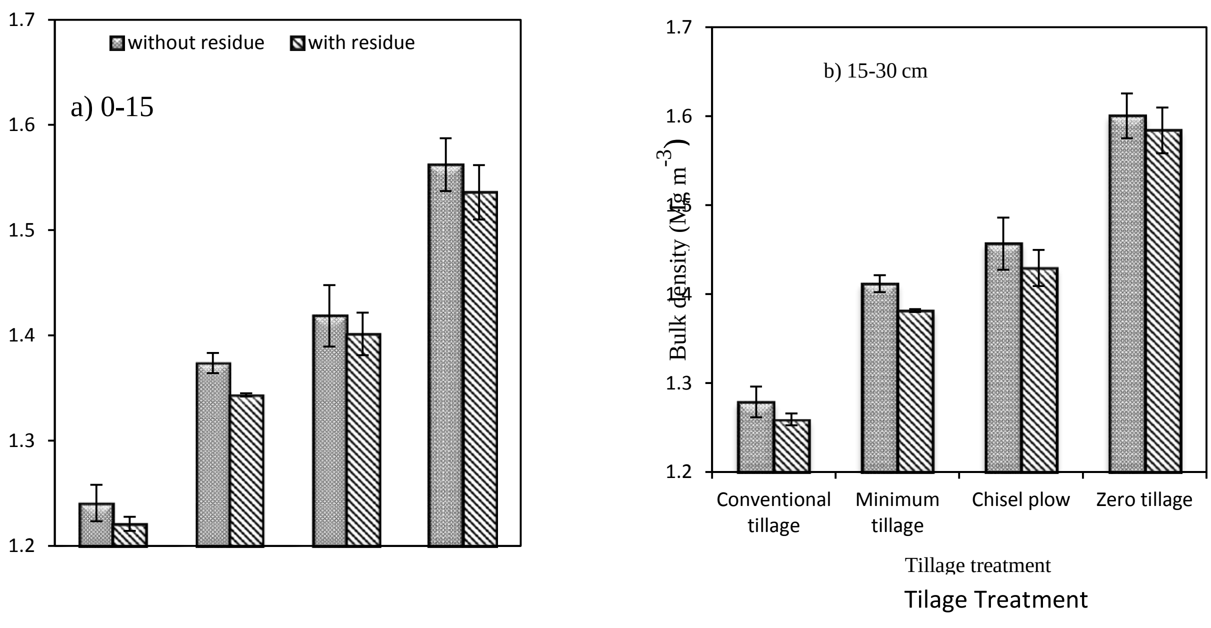


**Figure 2 a & b. Soil bulk density as affected by different tillage practices and residue incorporation: (a) 0-15 cm soil depth, (b) 15-30 cm soil depth indicating highest bulk density in zero tillage.**

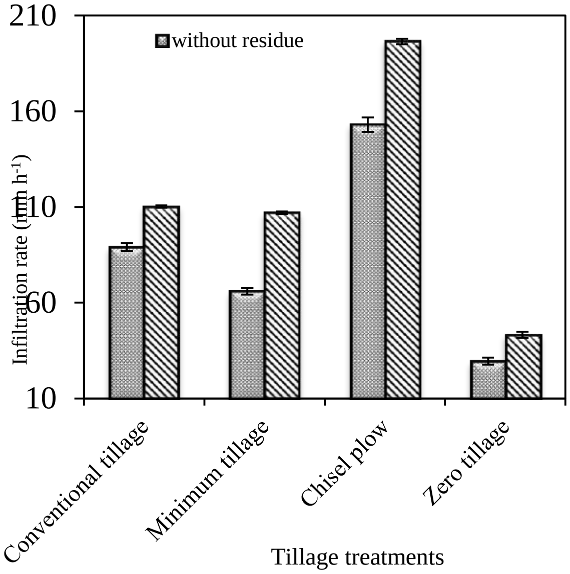


**Figure 3. Soil infiltration rate affected by different tillage practices and residue incorporation indicating highest infiltration in chisel plow.**

Higher water retentive capacity of soils indicated by higher field capacity and permanent wilting point under chisel plow might be due higher aggregation and organic matter content of soil. Chisel plow being non-inversion tillage causes lesser breakdown of aggregates and decomposition of organic matter through physical disintegration and oxidation. The micro pores of infiltration rate. Also the chisel plow breaks lesser aggregates and decomposes less organic matter [11] which might also increased the macroporosity of the soil over time thus the aggregates help in better retention of moisture, similarly organic matter being a charged entity imparts many fold higher water holding capacity to soil than other constituents [3;20]. Higher permanent wilting point under residue application could also be related to higher organic matter content of soil. Least water retentive capacity of zero tilled soil could be attributed to higher bulk density (Figure 2) than other treatments.

**Volumetric Water Content:**

The VWC throughout the sampling period in both the soil depths (0-15 and 15-30 cm), was significantly higher in chisel plow with residue retained than all other treatments (Figure 5). The conventional tillage and minimum tillage had equivalent VWC but zero tillage plots had significantly low VWC. Significantly higher VWC were observed in residue application as compared with no residue. Significant differences were observed with respect to days after sowing as well. Maximum VWC was observed at 158 DAS and minimum at 102 DAS.

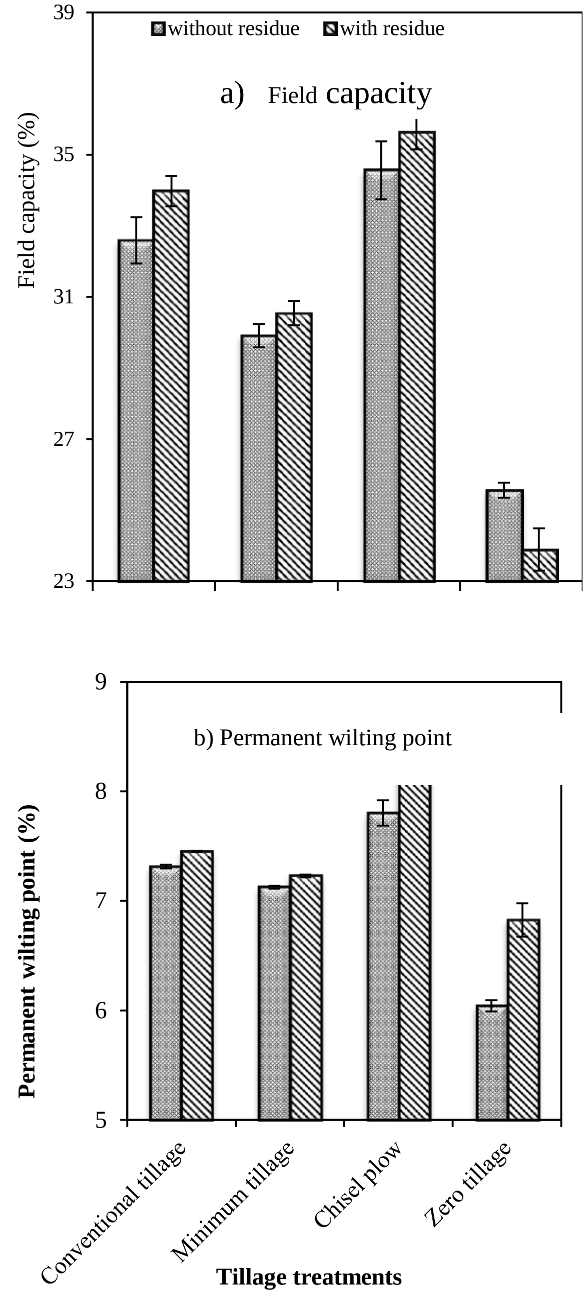


**Figure 4 (a & b). Field capacity (a) and permanent wilting point (b) of soil affected by different tillage practices and residue incorporation indicating highest moisture at field capacity and wilting point in chisel plow.**

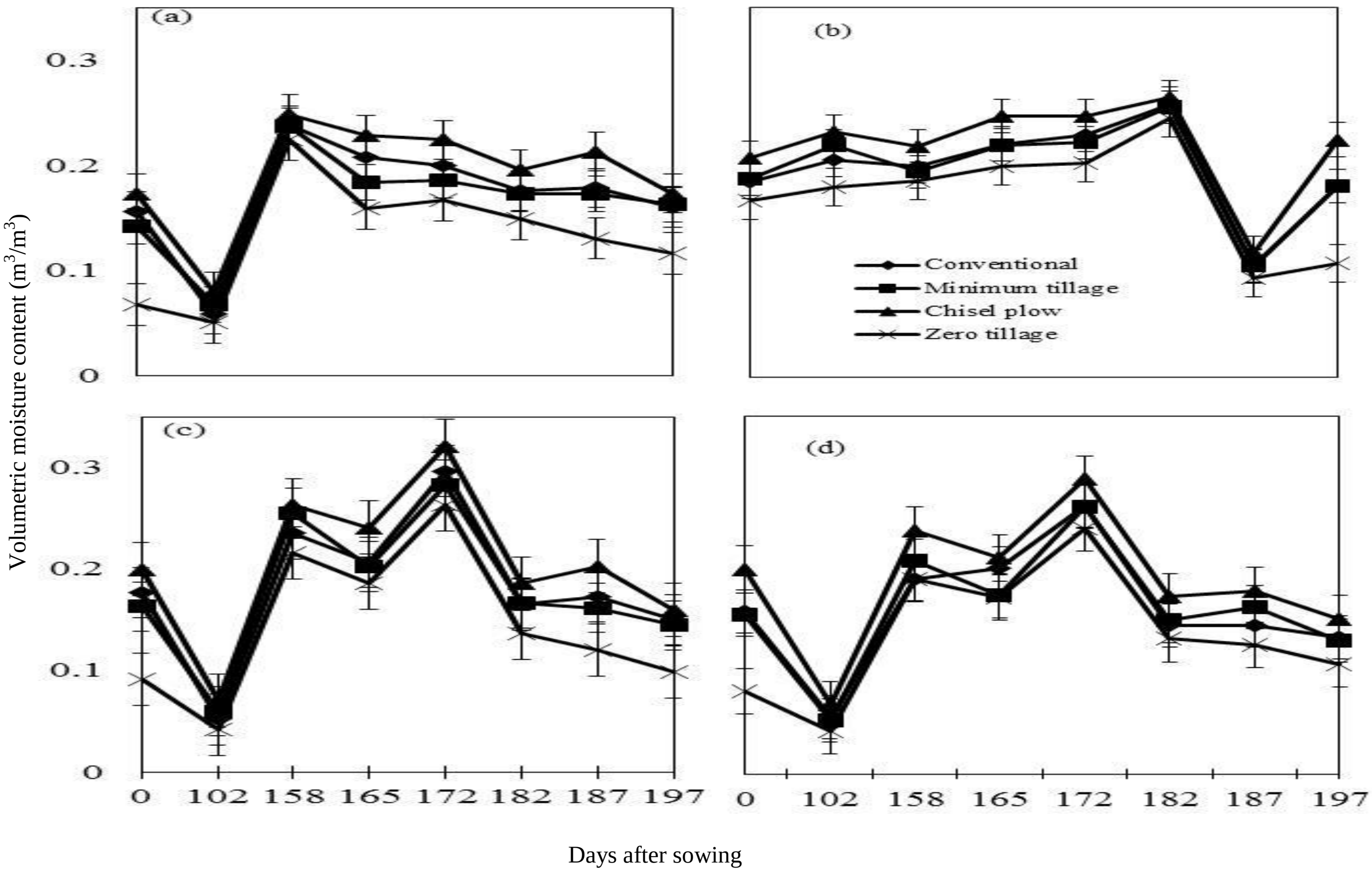


**Figure 5. Volumetric moisture content as affected by different tillage practices: (a) 0-15 cm soil depth without residue, (b) 0-15 cm soil depth with residue, (c) 15-30 cm soil depth without residue, (d) 15-30 cm soil depth with residue indicating volumetric moisture content high in chisel plow.**

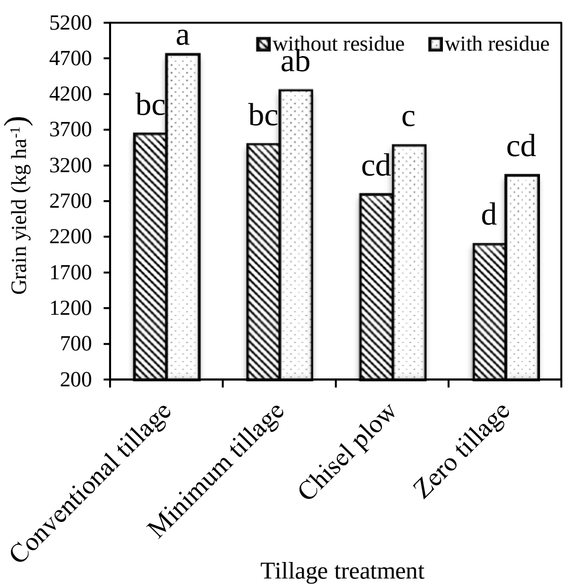


**Figure 6. Wheat grain yield affected by different tillage practices and residue incorporation indicating highest grain yield in conventional tillage**

Greater water content in chisel plow was due to higher water infiltration rate as shown in Figure 2, low bulk density (Figure 5) and thus increased porosity. The chisel plow is a non-inversion tillage practice that might have caused less evaporation loss as compared to conventional tillage in which the soil moisture is more exposed to aeration. Lowest moisture content under zero tillage was due to high bulk density of soil as shown in Figure 4, which hindered the entry of water. The applied residue retained higher water content due to more infiltration as observed in Figure 4, and water holding capacity as indicated in Figure 3 (a & b) caused by increased organic matter content which provides more surface area and charged sites to soil. Akhtar *et al.* (2005) [2] concluded that deep tillage practices were quite effective in preserving soil moisture content through precipitation and its utilization by the groundnut which is deep rooted crop. [7] who concluded that incorporation of residue using chisel plow attained significantly higher soil water content than other treatments when soil was wet, while when soil dries out incorporation of residue using moldboard plow attained significantly higher soil water content than all other treatments.

**Grain yield:** Higher grain yield of wheat was observed in conventional tillage and minimum tillage plots followed by plots tilled with chisel plow and then by zero tillage. The residue application increased the grain yield in all tillage plots but increment was not statistically appreciable except in conventional tillage. Among all treatment combinations zero tillage without residue gave the lowest wheat yield.

Keeping in view the higher infiltration rate, moisture retentive capacity and VWC under chisel plow, we expected higher or equivalent yield under chisel plow. However these benefits of chisel plow could not transform into higher yield than conventional systems. The lower grain yield in chisel plow may be due to problem in zero tillage drill, which resulted in poor germination of seeds (data not presented) and ultimately reduced the grain yield. The zero tillage drill used for wheat sowing was purchased from irrigated rice-wheat cultivated area where its benefits on wheat grain yield are well known, however, in rainfed areas of Pothwar this machine does not appear to be as effective as in irrigated areas. This necessitates the improvement of zero tillage sowing drill for rain-fed areas. These results are contrary to those of [ who reported superior wheat yield under deep tillage than shallow tillage.

## CONCLUSION:

Chisel plow improved the capture, retention and availability of water in soil than conventional practices as well as zero tillage. However, these improvements could not be transformed to greater yield of wheat due to poor germination caused by inferior performance of zero tillage drill under agro-ecological conditions of Pothwar.

## REFERENCES

1] Ahmed, M., S. Ahmad, M. Ashraf and M. A. Gill (2007). Partial budgeting of different sowing technologies of wheat. Sarhad. J. Agric., 23:4.

[2] Akhtar, J., S. M. Mehdi, O. Rehman, K. Mahmood and M. Sarfraz (2005). Effect of Deep Tillage Practices on Moisture Preservation and Yield of Groundnut under Rainfed Conditions J. Agri. Soc. Sci., 1: 98-101.

[3] Alam, M. K., N. Salahin, M. H. Rashid and M. A. Salam (2013). Effects of different tillage practices and cropping patterns on soil physical properties and crop productivity. J. Trop Resour. Sus. Sci., 1: 51-61.

[4] Berryman, C and B. D. Trafford (1974). Infiltration rates and hydraulic conductivity. Field drainage experimental unit technical bulletin, MAFF, Lonodon. pp. 16.

[5] Blake, G. R and K. H. Hartge (1986). Bulk Density by Core Method. In: A. Klute. (ed). Methods of sol analysis, Part 1. Amer. Soc. Agron. No. 9, Madison, Wisconsin, pp. 364-367.

[6] Bhutta, I. A (1999). Achievements and issues in 20th century in Small Dams (Rainwater Harvesting). Proc National Workshop Water Resources achievements and issues in 20th Century and Challenges for the next Millennium, pp: 64-69.

[7] Carthy, J.R. (2001). Conservation tillage and residue management to reduce soil erosion. Natural Resources Conservation Service. Department of Agricultural Engineering, Natural Resources and Conservation Service, Ext. Uni. Misso., G-1650.

[8] Dwyer, L. M and D. W. Stewart (1986). Leaf area development in field-grown maize. Agron. J., 78: 334-343.

[9] Evans, M.G., K.J. Eck, B. Gauck, J.M. Krejci, J.E. Lake and E.A. Matzat. (2000). Conservation tillage update: keeping soil covered and water clean in the new millennium. Clean Water Indiana Education Program. Agronomy Department, Purdue University 1: 1-16.

[10] Fowler, R. and J. Rockstrom. (2001). Conservation tillage for sustainable agriculture: An agrarian revolution gathers momentum in Africa. Soil and Tillage Research 61(1-2): 93-108.

[11] Javed, H.M.R., M. S. I. Zamir, A. Tanveer and M. Yaseen (2013). Soil physical properties and spring maize yield as influenced by different tillage practices and integrated use of poultry manure with synthetic fertilizers. J. Agric. Res., 51: 277-287.

[12] Jacinthe, P.A.; Lal, R. 2005. Labile carbon and methane uptake as affected by tillage intensity in a Mollisol. Soil & Tillage Research 80: 35-45.

[13] Kay, B.D. & VandenBygaart, A.J. (2002). Conservation tillage and depth stratification of porosity and soil organic matter. Soil Till. Res., 66:107–118.

[14] Laddha, K. C and K. L. Totawat (1997). Effects of deep tillage under rainfed agriculture on production of sorghum intercropped with green gram in western India. Soil Till. Res., 43: 241-250.

[15] Mann, R.A., M. Ramzan and A. Munir, 2008. Improving the sustainability of wheat production in irrigated areas of Punjab, Pakistan through conservation tillage technology. Int. J. Agri. Biol., 10: 249–54.

[16] Maia, S.M.F., Ogle, S.M. Cerri, C.C. Cerri, C.E.P. (2010). Changes in soil organic carbon storage under different agricultural management systems in the Southwest Amazon Region of Brazil. Soil Till. Res. 106, 177–184.

[17] Mati, B.M. (2005). Overview of water and soil nutrient management under smallholder rainfed agriculture in East Africa. International Water Management Institute (IWMI). Working paper 105.

[18] Muhammad, W., S. Shehzadi, S. M. Shah and Z. Shah (2010). Effect of tillage and crop residues management on mungbean crop yield nitrogen fixation and water use efficiency in rainfed areas. Pak. J. Bot., 42: 1781-1789.

[19] Oisat, K. (2005). Soil tillage. On-line Information Service for Non-chemical Pest Management in the Tropics. Available at: http://www.oisat.org/control_methods/ cultural practices/soil_tillage.html [Accessed on: 2/12/2006].

[20] Rahman, S. M and A. Islam (1998). Water transmission properties of two Bangladesh soils as affected by tillage practices. Soil water flux and hydraulic conductivity. AMA. Res., 10(3): 307-312.

[21] Razzaq, A., N. I, Hashmi, A. Majid and and P. R. Hobbs (2002). Evaluation of tillage systems for rainfed wheat. Pak. J.Agric.Res.,17: 27-34.

[22] Richards, L.A (1947). Pressure membrane extraction apparatus for soil solution. Soil Sci., 51: 377-386.

[23] Shafiq, M., A. Hassan, S. Ahmad and M. S. Akhtar (1994). Water intake as influenced by tillage in rainfed areas of Punjab, Pakistan. J. Soil Water Cons., 49: 302-305.

[24] Six, J.; Elliott, E.T.; Paustian, K. 1999. Aggregate and soil organic matter dynamics under conventional and no-tillage systems Soil Science Society of America Journal 63: 1350-1358

.[25] Steel, R. G. D., J. H. Torrie and M. A. Boston (1997). Principles and Procedure of Statistics: A biometrical approach. Mc Graw Hill Inc. New York. P. 633.

[26] Steiner, K.G. (2002). Producing in harmony with nature through conservation tillage. African Conservation Tillage Network. Information series No. 1, Harare: ACT.

[27] Topp, G.C and P. A. Ferre (2002). The soil solution phase–water content. Edited by Dane and Topp. Methods of Soil Analysis, Part 4. Physical Methods. SSSA Book Series, 5: 417-424.

[28] Veenstra, J.J., W.R. Horwath, J.P. Mitchell and D.S. Munk. (2006). Conservation tillage and cover cropping influence soil proprieties in San Joaquin Valley cotton tomato crop. California Agriculture 60 (3): 146-153.

[29] Wasaya, A.,M. Tahir, A. Tanveer and M. Yaseen (2012). Response of maize to tillage and nitrogen management. J. Anim. Plant Sci. 22(2): 452-456.

[30] Zamir, M. S. I., H. M. R. Javeed, W. Ahmed, A. U. H. Ahmed, N. Sarwar, M. Shehzad, M. A. Sarwar and S. Iqbal (2013). Effect of tillage and organic mulches on growth, yield and quality of autumn planted maize (zea mays l.) and soil physical properties. Cerc. Agron. Mol., 2: 17-26.